EARLY LIFE MEASURES OF SIZE AS RELATED TO WEIGHTS AND PRODUCTIVITY IN BEEF COWS AND CARCASS TRAITS IN STEERS

A Dissertation

by

SAMANTHA FERN CUNNINGHAM

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Chair of Committee, Andy D. Herring
Committee Members, Rhonda K. Miller
James O. Sanders
Jason E. Sawyer
Head of Department, H. Russell Cross

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ABSTRACT

The overall objective of this study was to investigate various measures of cattle size. Records from three separate studies (herds) at Texas A&M University were used to evaluate relationships of birth and weaning measures (n = 750) with size and productivity of females (n = 2,800 records from 450 animals) and carcass traits (n = 450) of steers. Cattle were F_1 crosses sired by Angus, Brahman, Boran, Gir, Indu-Brazil, Nellore, and Tuli. Relationships between cow traits and carcass traits of steer mates were also investigated. Animals were classified into Small, Medium and Large frame size categories based on weaning age hip heights.

Considerable differences in cow weight were observed within the same frame size category, and larger differences in weight within the same frame category was observed across study herds (which also differed in breed composition) than between different frame size categories within study herds in most cases; however, the large degree of confounding between frame size category and breed type prevented conclusive findings solely based on frame size category. Cow weight appeared to plateau at parity five, and in these data, this was considered to represent mature cow weight. Ranking of steer carcass weights based on frame score category followed expectations within study herds, but similar to cow weights these also varied considerably within the same frame category across study herds. Birth weight and cannon bone length accounted for 0 to 40% of the variation in parity-five weight of females and 1 to 52% of the variation in hot carcass weight of steer mates depending upon sire breed and study herd; use of weaning (weight, height, frame score) traits accounted for 2 to 46% of the variation in parity-five

weight of females and 13 to 67% of the variation in hot carcass weight of steer mates, again depending upon sire breed. Different patterns were observed between females and males depending upon sire breed. Based on results seen here weaning age designation of cattle frame size may not be a precise classification of mature size, similar frame size designations can vary considerably in weight across different genetic types, and mature size classification of beef cows alone does not guarantee productivity measures, particularly when frame size is confounded with genetic background.

DEDICATION

I dedicate this dissertation in the memory of my grandparents—Matthew and Pauline Cunningham and Earl and Helen Wolf. Without them, my parents would not be the voice of encouragement and the place to go home to that they are.

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I first would like to thank my committee members for not giving up on me, as this has taken longer than it should have. Drs. Herring, Miller, Sanders, and Sawyer, thank you for your patience, your advice, and most importantly your time.

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INTRODUCTION

Beef producers rely on animal size and weight to establish income. Many producers may overlook the fact that cattle sizes and weights across animal lifetimes are related, and many may not consider mature cow size implications in selection strategies to change traits of calves. This type of information is important for beef production system considerations, but is limited, particularly in regard to tropically adapted breeds. These considerations are important as producers attempt to increase production by increasing cattle growth such as through higher weaning weights, higher carcass weights, etc.

The goal of this project was to evaluate relationships among multiple size traits taken at different times in the lives of F_1 cattle that were sired by several tropically adapted breeds in central Texas. The objectives of this study were to: (1) evaluate cow productivity in regard to frame size designation determined as heifers at weaning, (2) evaluate early measures of calf size (at birth and weaning) for prediction of mature size in cows and carcass weight and other carcass traits in steer mates, and (3) evaluate relationships among size and productivity traits in cows and the relationships of these cow traits with carcass traits among their steer mates.

LITERATURE REVIEW

Specific considerations in regard to cattle size and associated production measures reported in scientific literature are reviewed below.

Genetic resources

Selection strategies in beef production systems should take into account all economically important traits. To meet the demand of quality beef, producers need to not only select for growth, maternal ability and production efficiency, but also for carcass characters (Splan et al., 2002). Recently, the beef industry has moved towards value-based marketing to better meet consumer preferences (Splan et al., 2002). This change has brought forth a possible need to better relate cow productivity traits to product endpoint characters. With a shift in beef cattle marketing and an increase of retained ownership, some have stated that production efficiency can be calculated by utilizing harvest weights and carcass traits (Ritchie, 2005). Newman et al. (1992) stated that a comprehensive evaluation of beef cattle genotypes would be incomplete without the specification of calf growth and carcass composition because this better describes the effect of genotype on life cycle productivity. However, evaluation of growth and carcass traits without considerations of associated cow size and productivity measures also provides an incomplete picture. Comprehensive studies that tie these components together are limited.

Breed differences in performance characteristics are important genetic resources for improving beef production efficiency (Cundiff et al., 1993) and meat composition and quality (Wheeler et al., 2001), and, these breed differences allow cattle producers to select breeds according to the production system (Freetly and Cundiff, 1998). Differences among families within breeds also provide genetic resources for important traits. Arango et al. (2002) reported high heritability estimates for cow weight and cow height and low heritability estimates for cow body condition score. Moderate to high heritability estimates have been reported for carcass traits (Splan et al., 2002; Nephawe et al., 2004). No type of animal can excel in all production environments. Breeds and crosses with some tropical adaptation have been used in the U.S. Gulf Coast region where heat tolerance is needed. Blending of desirable breed characteristics gives advantages of crossbreeding systems to purebred systems.

Crossbreeding systems also take advantage of hybrid vigor (heterosis). The greatest effects of heterosis are seen in lowly heritable traits when two completely divergent lines are crossed (Comerford et al., 1987), for instance, *Bos indicus* x *Bos taurus*, and the amount of heterosis seen in a *Bos indicus* x *Bos taurus* cross is generally two times (Cundiff et al., 1989), or three times (Koger, 1980) that seen in a cross of *Bos taurus* breeds. Lowly to moderately heritable traits are those such as early calf growth and survival and reproduction, and the greatest effect of hybrid vigor may be expected to be improvements in maternal ability and fertility (Cundiff, 1970), although heterosis affects most economic traits of beef cattle production (Gregory et al., 1978).

Cattle vary in body size between and within breeds. According to Cartwright (1979), size is important and is characterized by body weight at a given degree of maturity at a given body composition and has important correlated effects—growth rate and rate of maturity (Cartwright, 1979). Body size among and within breeds of cattle is variable, and this variability should be viewed as a useful genetic resource with the opportunity to increase production efficiency if properly managed (Cartwright, 1979). Due to the importance of body size to the establishment of market value, selection programs and crossbreeding objectives have begun to include traits pertaining to mature size (mature cow weight, mature height, and other body measurements, for instance), and an optimum size of beef cattle has been debated among researchers, breeders, and producers (Arango and Van Vleck, 2002). There may be no one optimum body size, and, for example, Dickerson (1978) recommended to choose the mature body size best for the breeding system and market and to then focus on improving performance for traits such as reproduction, growth rate, body composition, or milk. Beef producers have tried to increase traits such as weaning and slaughter weight (Nephawe et al., 2004); therefore, selection emphasis has been placed on lean, fast growing cattle, resulting in an increase in mature size (Arango and Van Vleck, 2002). Cattlemen and scientists have debated whether mature cow size has increased above levels necessary for optimum economic return (Nephawe et al., 2004). Over a period of 20 years, cow weights at 5 years at the Meat Animal Research Center in Clay Center, Nebraska, increased by nearly 160 kg on average and finished weights of steers increased by 125 kg (U.S. MARC, 1974; Cundiff et al., 2004). Scientists conducting the 2005 National Beef Quality Audit concluded that cattle were too big and that the cattle industry has opportunity to improve supply management through decreasing variation and controlling weight (Smith et al., 2006), yet increased weight per animal is viewed by many as increased production efficiency.

Body size has an important effect on the way that an animal responds to climate, feed resources, seasonal influences, and marketing strategies (Arango and Van Vleck, 2002). Approximately 60% of the total feed energy needed to produce and finish a calf through harvest is required by the cow for maintenance and production; therefore, it is recommended that cow size be matched to location, market, feed resources, and breeding system (Cartwright, 1979; Olson et al., 1982). Buttram and Willham (1989) stated that size and breed were practically inseparable, because the most likely way for commercial producers to change cow size was by using different breeds; however, that may likely not be the case presently (2012) as many breeds appear similar for size.

Body size classification

Frame score is a commonly used method of describing skeletal size in cattle, and hip height relative to age is converted to frame score, a linear measurement that, according to Dolezal et al. (2002), is used to evaluate the lean-fat ratio potential of an individual. Frame size is defined by hip height at a particular age and is correlated with growth rate (Vargas et al., 1999), it is most valuable as a predictor of weights at puberty, maturity, and slaughter, and it is the easiest, most useful method for estimating relative skeletal size (Hammack and Gill, 2009). A preference for increased frame size in cattle may be justified, as a positive correlation exists between frame size and growth rate in beef cattle (du Plessis et al., 2006), but the size must be considered relative to production environment. The effect of cow frame size on efficiency has been evaluated, but has been found to be confounded with breed composition (Buttram and Willham, 1989; Taylor et al., 2008), in many cases creating difficulty determining whether differences in performance of cattle were due to differences in frame size or breed composition (Olson, 1993).

There are direct economic indicators related to cattle size. Feeder calf grades are classified into small, medium and large categories (USDA, 2000), with distinctive price discounts for calves classified as small. Expected weights at which large, medium, and small frame feeder steers should have 0.5 inches (12 to 13 mm) of fat cover are > 1250 lb (567 kg), 1100 (499 kg) to 1250 lb, and < 1100 lb, respectively; corresponding weights for large medium and small heifers are > 1150 lb (522 kg), 1000 (454 kg) to 1150 lb, and < 1000 lb, respectively. These three frame size designations (USDA Small, Medium and Large) have been said to represent numerical frame scores of under 4.0, 4.0 to 5.5, and over 5.5, respectively (Hammack and Gill, 2009). Typically carcass weights are acceptable in the 600 to 900 lb (272 to 408 kg) range, but discounts may be applied outside of this range depending upon packing plant and targeted beef program.

Five months of age is the earliest age listed on the Beef Improvement Federation frame score table (Hough et al., 2002). Cannon bone length can be an alternate early indicator of mature size and weights at different ages (Meyer, 1995), as it can be measured as early as birth. Meyer (1995) found greater genetic correlations between cannon bone length and mature weight than between hip height and mature weight in Hereford cattle. Some studies have classified cows into different size categories such as small, medium and large, and, several of these are presented in Table 1.

Frame score alone does not describe animal size and weight. Body condition is another important consideration and has been documented to affect cow maintenance, growth, reproduction, milking ability, mature size, and productive lifespan (Klosterman et al., 1968; Northcutt et al., 1992). It is obvious that body condition is related to weight, and Klosterman (1971) reported that weight alone is not sufficient to describe mature beef cow size. According to Hammack and Gill (2009), "The most useful measure of body size is weight at standard fatness or condition, which also accounts for differences in muscling, a shortcoming of the frame score system. Frame score is most valuable as a predictor of weights at slaughter, puberty and maturity." Northcutt et al. (1992), used single weight records collected at or near weaning when condition scores were also taken and found that condition score of Angus females was more highly correlated with weight than height and recommended that mature size in beef cows should include an adjustment for body condition score (degree of fatness) at a given weight.

Relationships of cow size with measures of productivity – calf traits

Stewart and Martin (1981) reported that as cow weight increased in Angus and Milking Shorthorn cows, average calf weaning weight increased, the number of years in the herd decreased, the number of calves produced decreased, and therefore there was a decrease, although not significant, in total weight of calf produced per cow. In a study evaluating size classification and productivity in Hereford cows, Olson et al. (1982) reported that large cows (566.8 $\pm$ 7.86 kg) weaned more weight of calf/cow exposed than small (450.9 $\pm$ 8.02 kg), medium (517.1 $\pm$ 8.38 kg) and very large (649.9 $\pm$ 11.85 kg) cows. Calves out of large Hereford cows were the heaviest at birth, the fastest growing to weaning, and had the highest adjusted weaning weights (Olson et al., 1982). Fiss and Wilton (1993) also found a positive association between birth weight of calf and cow weight in Angus, small rotation systems (Angus, Gelbvieh, Pinzgauer, and Tarentaise) or large rotation systems (Charolais, Maine Anjou, and Simmental). Calves out of small Hereford dams had the slowest preweaning growth rates and lowest weaning weights (Olson et al., 1982). Olson et al. (1982) also reported that calves out of very large Hereford cows had below average adjusted weaning weights, and the authors suggested that, although the genetic potential for early growth should have been transmitted by very large cows, it was not expressed because of their poorer milking ability. It is unclear if their poor milking ability was due to their weight or body condition, as females that produce fewer pounds of milk often become heavier conditioned than higher milking cows, and therefore, may have been classified into a larger size group. Optimal milk production should increase with cow size in order to maintain full expression of growth potential and to support maximum production efficiency (Cartwright, 1979; Olson et al., 1982).

Vargas et al. (1999) found frame size did not have an effect on body condition score in second- or third and greater-parity Brahman cows; however, large framed, first-parity females achieved significantly lower condition scores than did those in the small and medium frame groups.

Frame size has been shown to affect birth weight of calves out of first-, second-, and third and greater-parity groups of Brahman females (Vargas et al., 1999). Likewise, when du Plessis et al. (2006) evaluated Simmentaler cross, Bonsmara cross, Afrikaner cross, and Nguni cowherds, they found that breed had a significant effect on birth weight, adjusted weaning weight, and total gain of calves, and these weights were influenced by the frame size of dam with larger females weaning heavier calves across all breeds, although average daily gains of calves out of Afrikaner and Nguni females were not different from one another. Taylor et al. (2008) reported that, among all parity groups of Santa Gertrudis dams, calves out of large framed (> 135 cm hip height at 18 mo) females were from 2.2 to 9.8 kg heavier at birth ($P < 0.05$) than calves out of small or medium framed dams. Vargas et al. (1999) found that calves from large frame (134 to 145 cm hip height at 18 mo.) Brahman cows were approximately 8 kg heavier at birth compared to calves from small frame (116.0 to 125.5 cm hip height at 18 mo.) cows out of first-, second-, and third and greater-parity groups. As first-parity females, Santa Gertrudis females in the large frame size group weaned calves with higher average daily gains than those from small framed cows (Taylor et al., 2008). Calves from small frame, first-parity Brahman females were lighter at weaning than those out of medium and large frame cows versus the weaning weights of calves out of second-parity Brahman females that were not affected by frame size (Vargas et al., 1999). In second-parity Santa Gertrudis cows, the calves from medium frame cows had higher preweaning average daily gains (ADG) ($P < 0.05$) than calves out of small and large framed dams, and calves from third and greater-parity females that were medium and large framed had higher preweaning ADG than those out of small framed cows (Taylor et al., 2008). In the third and greater-parity group, small and medium frame Brahman females weaned calves of similar weights that were lighter than those weaned by large frame cows (Vargas et al., 1999).

Relationships of cow size with measures of productivity – fertility traits

Selection for increased frame size likely has increased growth rate, but its impact on female fertility traits may have been negative (Vargas et al., 1999). Reproductive efficiency is the most economically important aspect of beef production, and how mature cow size affects reproductive performance is important (Buttram and Willham, 1989). Small Angus heifers bred as yearlings to calve at 2 years of age had a higher calving rate than large Angus heifers (Buttram and Willham, 1989); but Vargas et al. (1999) found frame size did not influence calving rate in first-parity Brahman heifers that were not exposed for the first time until they were 24 months of age.

The frame size of heifers has been shown to significantly affect their calving rate as second-parity females (Taylor et al., 2008). In second-parity Santa Gertrudis cows, those that were categorized large framed as heifers had a calving rate 41% less than the heifers categorized as medium and small frame size (Taylor et al., 2008). Olson (1994) also found large differences in pregnancy rate in small, medium, and large frame second-parity Hereford females of 74.9, 51.8, and 34.5%, respectively. Vargas (1999) found frame size to have a significant effect on calving rate of second-parity Brahman dams, as fewer than 64% of females that weaned their first calf calved the following year. Large frame females (41.0 ± 8.38%) had calving rates that were 25% lower than that of small (65 ± 5.42%) and medium (69.0 ± 4.85%) frame females.

In third and greater-parity females, of various breeds, calving rate has been significantly higher for small frame cows than for medium and large frame cows (Buttram and Willham, 1989; Vargas et al., 1999; Taylor et al., 2008). Vargas et al.

(1999) found a frame score by body condition score interaction in third or greater-parity Brahman females. Large framed females with a BCS 3 had higher calving rates than medium frame cows with a BCS 3. Within BCS 4, large frame cows had higher calving rates than both small and medium frame cows. Large frame cows with a BCS of 5 or 6, had lower calving rates than did small and medium frame cows. In that study, cows were not culled unless they were open for two consecutive years. Consequently, cows that did not conceive as lactating 3 year olds could have re-entered the data set as lactating 5 year olds; however, the pregnancy data as non-lactating 4 year olds and weight and other data from the calf born at 5 years old were not included in their analysis.

Vargas et al. (1999) found frame size affected weaning rate in first- and second-parity Brahman females. Small and medium frame Brahman females had higher weaning rates than large frame cows and heifers (Vargas et al., 1999). Weaning rates for large frame, second-parity Santa Gertrudis females were also lower than weaning rates for small and medium frame cows (Taylor et al., 2008). Frame size did not influence weaning rate in third or greater-parity Brahman females (Vargas et al., 1999). Olson (1994) reported that the disadvantages in fertility of larger type cattle diminished with increasing age in composite, Brahman, or Angus herds.

Weight of calf weaned per cow exposed is a function of calving rate, calf survival rate, and calf weaning weight (Vargas et al., 1999). Taylor et al. (2008) concluded that small and medium frame Santa Gertrudis females had greater calving and weaning rates and weaned more kilograms of calf per cow exposed than large frame females. In first-parity females, kilograms of calf per cow exposed were comparable between small and medium frame dams, and both dam types weaned more kilograms of calf per cow exposed than the large framed cows (Vargas et al., 1999). In the third or higher parity group, the effect of frame size on production per cow was not significant, however, large frame cows produced more ($P > 0.05$) calf weight per cow exposed than did small or medium frame cows (Vargas et al., 1999). Lopez et al. (1993) found that the weaned calf weight per cow exposed decreased by 17 kg for each 100 kg increase in cow weight in Retinta, a dual purpose, Spanish breed (OSU, 2012). Vargas et al. (1999) concluded that frame score affected reproductive and production performance in Brahman cattle, and that the effect of frame score on reproductive performance was greater at younger ages than in mature females. Optimum production efficiency was seen in mature Hereford females of average or slightly larger than average size (Olson et al., 1982).

Relationships of cow size with carcass traits

Beef cattle producers should consider the beef female and her sibling brothers and/or the offspring that she produces that may eventually be marketed as fed cattle. Nephawe et al. (2004) reported that selecting for mature cow weight and/or height can be expected to change size while not be expected to cause large changes in carcass and meat traits (retail product percentage, marbling score, and tenderness). These authors also found a high, positive genetic correlation (0.81) between hot carcass weight and mature cow weight when analyzing mature weights of females and the carcass weights of paternal half-sib steers and suggested that reducing cow weight without considering hot carcass weight may lead to carcasses receiving discounts for being too light. A trend in the opposite direction could also been seen where large mature cow weights may lead to carcasses receiving discounts for being excessively heavy.

Cow size can have effects on postweaning traits of progeny similar to trends seen in preweaning traits (Olson et al., 1982). Steer calves out of medium and large dams appeared to grow faster in the feedlot than did calves out of small and very large dams, although differences were not significant (Olson et al., 1982). When considering efficiency (kg TDN/kg gain) during the postweaning period, calves out of very large dams were the least efficient when compared to calves out of small, medium, and large dams (Olson et al., 1982). Fiss and Wilton (1993) found that increasing cow weight had no effect on days on feed, average daily gain, feed intake, or market weights and that increased cow weight had no significant effect on market weight or hot carcass weight of her male calves; although a trend toward increased hot carcass weight was seen.

Across three breeding systems: Hereford, small rotation (Angus, Gelbvieh, Pinzgauer, or Tarentaise sires), and large rotation (Charolais, Maine Anjou, or Simmental sires) marbling tended to decrease with increased cow weights (Fiss and Wilton, 1993). When Hereford calves were harvested on an age-constant basis (440 d), dam size was shown to affect harvest weight, carcass weight, rib eye area, and yield grade, and these effects due to cow size were due to the significant effects of cow size on preweaning traits. Steers from small and large dams had the leanest carcasses and the greatest yields of edible product (Olson et al., 1982). At a constant harvest weight (486 kg), the effects of cow size on preweaning growth traits were removed and cow size significantly affected rib eye area, trimmed retail cut weight, and yield grade (Olson et al., 1982).

Weight traits, including mature cow weight and hot carcass weight, have intermediate optimums (Nephawe et al., 2004). Mature weight has been shown to have low genetic correlation with retail product percentage (-0.05), fat trim (-0.02), and adjusted fat thickness (-0.03) and not different from zero (Nephawe et al., 2004). Different from this, in Hereford, Angus, and Charolais cattle and their crosses, Speer (1993) found mature weight of cows to be highly, negatively (-0.54) genetically correlated with fat thickness of bulls and steers harvested on a weight-constant basis, and they concluded that cows by sires that were selected for lower fat thickness of steer progeny would be larger at maturity. Nephawe et al. (2004) also reported mature weight was lowly to moderately correlated to carcass bone weight (0.25) and longissimus muscle area (0.34) suggesting that sires selected for producing daughters who are smaller at maturity would be expected to produce steers with smaller percentages of bone and smaller longissimus muscle area. Mature weight has been reported to be low and negatively correlated with marbling (Speer, 1993; Nephawe et al., 2004) and low and positively correlated with tenderness (Warner-Bratzler shear force) (0.15) (Nephawe et al., 2004). By selecting for smaller mature cow weights, producers should slowly increase marbling and tenderness (both, decreased shear force and increased taste panel tenderness) in steers (Nephawe et al., 2004).

Information is limited when considering maternal effects on carcass traits (Crews and Kemp, 1999; Splan et al., 2002; Nephawe et al., 2004), whereas maternal effects on preweaning traits have been included in many evaluations. Few have reported correlations between maternal genetic effects on weaning weight and direct genetic effect on carcass traits. Correlations between maternal genetic effects on weaning weight and direct genetic effects on carcass traits were usually low; however, weaning weight and hot carcass weight were highly, positively correlated (Crews and Kemp, 1999). Selection for most carcass traits would not be expected to result in important changes in maternal ability because most of the correlations between maternal genetic effects for weaning weight are low (Splan et al., 2002). Researchers have stated that direct selection for many carcass traits can be effective, as heritability estimates for several carcass traits are moderate to high (MacNeil et al., 1984; Splan et al., 2002; Nephawe et al, 2004); likewise, variance in most carcass traits due to maternal effects has been found to be small or near zero (Splan et al., 2002; Nephawe et al., 2004). Speer (1999) also found estimates of maternal heritability of carcass traits to be low.

Summary

Beef cattle breeding objectives have evolved to meet production standards, resources, consumer demands, and marketing practices (Nephawe et al., 2004). In order to meet demand for quality beef, beef cattle producers need to consider growth, maternal ability, production efficiency, and carcass traits (Splan et al., 2002). Producers have attempted to improve overall growth traits; however, through selection, mature cow size may have been increased beyond levels for optimum economic returns (Nephawe et al., 2004) as high maintenance costs are associated with large cows (Fiss and Wilson, 1992), and economic conditions result in continually higher input costs.

Optimum cow size is dependent on the production system (Arango and Van Vleck, 2002), and researchers have recommended moderate cow size, to allow females to maintain adequate body condition within the nutritional levels in commercial conditions while producing progeny with adequate growth rates and acceptable carcass weights (Olson, 1994; Vargas et al., 1999). Selection for optimum mature cow size could be improved through knowing the relationship of mature cow size and economically important traits, both carcass traits and female productivity (Nephawe et al., 2004). As a result, the objectives of this project were to: (1) evaluate cow productivity in regard to frame size designation determined as heifers at weaning, (2) evaluate early measures of calf size (at birth and weaning) for prediction of mature size in cows and carcass weight and other carcass traits in steer mates, and (3) evaluate relationships among size and productivity traits in cows and with carcass traits among their steer mates.

MATERIALS AND METHODS

Animals

Records from three separate studies at Texas A&M University were available for calving, weaning, and carcass characteristics of F_1 calves sired by Angus, Brahman, Boran, Gir, Indu-Brazil, Nellore, and Tuli bulls, as well as size and reproductive traits of the F_1 females. These individual studies (referred to as I, II, III) are described below.

Dataset I

In 1993 and 1994, 15 Brahman bulls were mated via artificial insemination to Angus and Hereford cows, older than three, at the Texas A&M Research Center at McGregor, TX. Kuykendall (1996) analyzed the birth, weaning, and carcass traits of the F_1 calves. Riley (2000) and Key (2004) reported early reproductive traits, weight and condition of the F_1 females.

Dataset II

Data were collected as part of the Texas Agricultural Experiment Station project S-6509, "Evaluation of Zebu Breeds for Beef Production." The research was conducted at the USDA Blackland Conservation Research Center at Riesel, TX, and at the Texas Agricultural Research Center at McGregor, TX. Angus, American Gray Brahman, American Red Brahman, and Brazilian Gir, Indu-Brazil, and Nellore bulls were bred to two year old and older Hereford cows via artificial insemination in 1982, 1983, 1984, and 1985. Paschal et al. (1991) reported the calving and weaning characteristics of the F_1 calves produced in this study, and Paschal et al. (1995) reported the postweaning and feedlot growth and carcass characteristics of the F_1 steers. Riley et al. (2001 a, b) reported the reproductive, maternal, size, udder, mouth, longevity, and lifetime productivity traits of the F_1 females.

Dataset III

Multiparous Hereford and Angus cows were artificially inseminated in 1991 and 1992 to Tuli (n = 9), Boran (n = 8), and Brahman (n = 15) sires at the Texas A&M Research Center at McGregor, TX. Boran and Tuli semen was imported into the United States from Australia. The Brahman semen, representative of the breed in the early 1990s, was obtained from U.S. purebred breeders and commercial breeding services. Herring et al. (1996) reported birth, weaning, and post weaning performance of the F_1 animals in this study, as well as, the carcass characteristics of the steers produced from the same matings. Ducoing (2002) analyzed the maternal and reproductive performance of these F_1 females that were sired by Brahman, Boran, and Tuli bulls as 7 and 8 year olds, and Cunningham (2005), Maiga (2006), and Muntean (2011) evaluated these F_1 females as older cows for reproductive and maternal performance and longevity.

Statistical analyses

Frame score was calculated on all animals using weaning hip height and corresponding age in days with the Beef Improvement Federation equation (Dolezal et al., 2002); frame size categories of small, medium, and large were then assigned according to Hammack and Gill (2009) with small category designated for less than 4.0, medium category designated for those over 4.0 and but less than 5.5, and large category designated for animal over 5.5.

The variables considered in this study were analyzed through mixed model procedures of SAS in datasets that included all three studies (referred to below as herds). Birth weight, cannon bone length, weaning weight, weaning hip height, and frame score at weaning among the approximately 750 F_1 calves with this information that were evaluated using a model that includes herd, sex within herd, breed of sire within herd, breed of dam within herd, birth year within herd, and sire within sire breed within herd. All possible two-way interactions between main effects were initially tested for significance, and those that were significant ($P < 0.25$) were included in the final models. In the birth weight and cannon bone length models, birth date within birth year within herd was included as a covariate. In the weaning weight and weaning height models, weaning age within birth year within herd was included as a covariate.

Carcass weight, fat thickness, USDA yield grade, rib eye area, and marbling score on approximately 450 steers was evaluated using a model that included breed of sire within herd, breed of dam within herd, birth year within herd, herd, and sire within breed of sire within herd. Harvest age within birth year within herd was used as a covariate.

Cow weight repeated records (approximately 2,800 records from approximately 450 cows) taken annually at calf weaning and/or pregnancy determination were evaluated using a model that included sire breed of dam within herd, dam breed of dam within herd, year within herd, parity within herd, herd, dam's sire within sire breed of dam within herd. Models that included lactation status and body condition score were tested to evaluate their effects on these variables. All possible two-way interactions between main effects were initially tested for significance, and those that were significant ($P < 0.25$) were included in the final models.

Simple correlations among various size measures throughout animals' lives were evaluated, and linear regression was used to predict future size traits from early life measures. Regression models were used to assess birth weight and cannon bone length as well as and weaning weight and hip height in their potential to predict cow weight at parity five and carcass weight of steers. Correlations of the sire solutions from the cow analyses and the steer analyses were compared in an attempt to relate female and male traits and assess sire value for daughter productivity vs. son carcass evaluations.

RESULTS AND DISCUSSION

Results are presented in three major sections of (1) cow size and body condition score considerations, (2) carcass traits of steer mates to cows, with particular emphasis on carcass weight, and (3) relationships between sex specific traits of cow weight and steer carcass weight. There is also brief discussion at end regarding distributions of weaning frame score category across breed types and study herds. It should be clear to the reader that the three studies evaluated here were not developed to be compared to one another, but an attempt was made to combine datasets of research populations at the same location under similar management. Due to the level of confounding involving sire breed and frame score category designation, no results based on frame score designation alone are presented.

Cow size and cow body condition

Cow size is an important consideration because it affects cow maintenance, reproductive ability and calf growth; it can be measured using variables such as weight and height. Body size among and within breeds is variable, and, when properly managed, size can be a useful genetic resource to improve production efficiency (Cartwright, 1979).

Correlations involving calf measures with cow weight and body condition score at first, second, third, and fifth parity

The ability to predict cow mature size from measures early in life has been and remains of interest to producers. Previous studies have estimated genetic parameters for mature weight and early weight measurements in beef cows (Speer, 1993; Nephawe, 2003). Through relating these early weight measurements to later and/or mature weights, producers can estimate mature cow size when making selection decisions based on weights taken early in the lives of beef cows. Because birth weight and weaning weights are routinely measured in many beef herds, these traits were evaluated as how they related to later measure of cow weight.

Simple correlations among early growth measurements and cow weight and cow body condition score (BCS) measured at weaning of the first, second, third, and fifth parity for each of the three studies (herds) are found in Tables 1, 2, and 3, respectively. First, second, third, and fifth parity weight measurements were used rather than at cow ages because females in Studies I and III were bred as heifers to calve at 2 years of age and females in Study II were bred as long yearlings to calve at 2.5 years of age.

In study (herd) I and study (herd) II, birth weight (BWT) was more strongly correlated to cow weight at the fifth parity (r = 0.63 and 0.44, respectively) than to cow weight at earlier parities (Tables 1 and 2). Alternatively, this trend was not similar in study III, as cow weights at parity two and three were slightly more related to BWT (Table 3). Correlations between weaning weight (WWT) and cow weight at the second, third, and fifth parities were greater than those between WWT and cow weight at the first parity in studies II (r = 0.22) and III (r = .27) as compared to r of 0.12 in study I. Furthermore, correlations between WWT and cow weight at the second, third, and fifth parities in study I were very different from those in studies II and III as they were not different from zero. Frame score at weaning (FS), which was based on weaning hip height relative to age, was more related to cow weight ($P < 0.05$) at parities one and two than parity three or five in study I. In study II, FS was more correlated with cow weights at parities three and five, and in study III, FS was strongly and positively correlated (P < 0.05) with cow weight at parities 1, 2, 3, and 5. Only in study I were BWT and cow BCS correlated, which may be in part due to the level of variability in BCS observed (4.9 to 5.8); BWT and BCS at parity 5 were low to moderately correlated (P < 0.10) at each parity. Study II had the only set of cows where cannon bone length (CBL) was correlated (P < 0.05) with BCS at parity 2 (r = -0.26). Weaning weight was correlated with BCS at parity 3 in study II (P < 0.05) and with BCS at parities 2 and 3 (P < 0.05) with a trend for parity 5 (P < 0.10) in study III. In studies I and III, FS and parity 1 BCS were correlated (P < 0.10); however, the correlation was positive (r = 0.21) in study I and negative (r = -0.16) in study III.

In all studies, cow weight at parity 1 was positively correlated with BCS at parity 1. Cow weight at parity 1 in study I was also moderately correlated with BCS at parity 2 (P < 0.05) and BCS at parity 3 (P < 0.10). In study II, cow weight at parity 1 was moderately correlated (P < 0.05) with BCS at parities 2 and 5. In study III, cow weight at parity 1 was negatively correlated with BCS at parity 5. Body condition score at the first parity was correlated with weight (P < 0.10) and BCS (P < 0.05) at parity 2 in study I. In study II, BCS at parity 1 was correlated (P < 0.05) with cow weight at parities 2, 3 and 5, as well as BCS at parities 2 and 5. Cow body condition score at parity 1, in study III, was correlated with BCS at parities 2 and 3 (P < 0.05) and with cow weight at parity 5 (P < 0.10).

Body condition score at parity 2 was correlated with cow weight at parities 3 ($P < 0.10$) and 5 ($P < 0.05$) and BCS at parity 5 in study I. In study II, BCS at parity 2 was correlated with cow weight and body condition score at parities 3 and 5. BCS at parity 2, in study III, was only correlated with BCS at parities 3 and 5 ($P < 0.05$). In studies II and III, BCS at parity III was correlated with BCS at parity 5. Parity 3 BCS in study III was also correlated with cow weight at the fifth parity. In all studies, BCS at the fifth parity was correlated with cow weight at the fifth parity ($P < 0.05$).

These three studies were not developed to be compared to one another and simply represent three specific research populations at the same location and similar management where early calf measures of birth weight and cannon bone length were available in addition to multiple size measures later in life. Within each study herd, there are also various sire breeds and specific year effects that are confounded with these studies that influence interpretation across studies. However, in these groups of cows it is apparent that the relationships with birth weight, cannon bone length, weaning weight and weaning hip height (or frame score) and cow weight later in life are not consistent, and the sources of these could be due to a variety of genetic influences, environmental/management effects, and, potential interactions.

Northcutt et al. (1992) concluded that the degree of fatness of beef cows is an important consideration when considering cow weight, as they found that cow condition score more highly correlated with weight than with height when evaluating Angus females. Arango et al. (2002) agreed that selection for condition score would exhibit a correlated response with weight. Arango et al. (2002) also concluded that selection would have been effective for weight or height, and would produce correlated responses for both measures of growth, but selection for condition score would not be as effective.

Table 1. Pearson correlations for birth, weaning, and cow weight traits at parity 1, 2, 3, and 5 in Brahman-sired F_1 females born in 1994 and 1995[a]

Trait	CBL	WWT	WHT	FS	Weight1	BCS1	Weight2	BCS2	Weight3	BCS3	Weight5	BCS5
BWT	0.57*	0.21*	0.26*	0.37*	0.25*	-0.09	0.28*	0.06	0.34*	0.17	0.63*	0.27†
CBL		-0.03	0.20†	0.33*	0.32*	0.14	0.14	-0.01	0.17	-0.03	0.45*	0.12
WWT			0.82*	0.60*	0.12	-0.04	-0.05	-0.13	0.02	-0.09	0.13	0.04
WHT				0.80*	0.22*	0.10	0.29*	0.02	0.09	-0.08	0.50*	0.32†
FS					0.31*	0.21†	0.32*	0.12	0.15	-0.04	0.53	0.20
Weight1						0.58*	0.44*	0.24*	0.43*	0.24†	0.35*	-0.07
BCS1							0.19†	0.29*	-0.03	0.03	0.02	-0.06
Weight2								0.72*	0.43*	0.18	0.72*	0.40*
BCS2									0.25†	0.14	0.37*	0.26†
Weight3										0.72*	0.38*	-0.12
BCS3											0.06	-0.10
Weight5												0.59*

[a]BWT = birth weight, kg; CBL = cannon bone length, cm; WWT = weaning weight, kg; WHT = weaning height, cm; FS = frame score; Weight1 = cow weight at parity-1; BCS1 = cow body condition score at parity 1; Weight2 = cow weight at parity 2; BCS2 = cow body condition score at parity 2; Weight3 = cow weight at parity 3; BCS3 = cow body condition score at parity 3; Weight5 = cow weight at parity 5; BCS5 = cow body condition score at parity 5.

†Correlations are different from zero at $P < 0.10$

*Correlations are different from zero at $P < 0.05$

Table 2. Pearson correlations for birth, weaning, and cow weight traits at parity 1, 2, 3, and 5 in Angus-, Brahman-, Gir-, Indu-Brazil-, and Nellore-sired F_1 females born in 1982, 1983, 1984, and 1985[a]

Trait	CBL	WWT	WHT	FS	Weight1	BCS1	Weight2	BCS2	Weight3	BCS3	Weight5	BCS5
BWT	0.68*	0.13	0.43*	0.51*	0.37*	0.01	0.33*	-0.07	0.34*	-0.05	0.44*	0.06
CBL		-0.10	0.27*	0.45*	0.06	-0.08	-0.04	-0.26*	0.08	-0.14	0.18†	-0.07
WWT			0.63*	0.43*	0.22*	0.06	0.42*	0.06	0.44*	0.24*	0.30*	-0.05
WHT				0.93*	0.24*	-0.06	0.37*	-0.03	0.48*	-0.01	0.40*	-0.06
FS					0.18†	-0.12	0.32*	-0.04	0.43*	-0.05	0.40*	-0.09
Weight1						0.62*	0.58*	0.20*	0.65*	0.05	0.64*	0.22*
BCS1							0.25*	0.23*	0.29*	0.16	0.28*	0.19*
Weight2								0.43*	0.82*	0.22*	0.78*	0.25*
BCS2									0.40*	0.20*	0.26*	0.35*
Weight3										0.34*	0.75*	0.27*
BCS3											-0.001	0.28*
Weight5												0.34*

[a]BWT = birth weight, kg; CBL = cannon bone length, cm; WWT = weaning weight, kg; WHT = weaning height, cm; FS = frame score; Weight1 = cow weight at parity 1; BCS1 = cow body condition score at parity 1; Weight2 = cow weight at parity 2; BCS2 = cow body condition score at parity 2; Weight3 = cow weight at parity 3; BCS3 = cow body condition score at parity-3; Weight5 = cow weight at parity 5; BCS5 = cow body condition score at parity 5.

†Correlations are different from zero at $P < 0.10$

*Correlations are different from zero at $P < 0.05$

Table 3. Pearson correlations for birth, weaning, and cow weight traits at parity 1, 2, 3, and 5 in Brahman-, Boran-, and Tuli-sired F_1 females born in 1992 and 1993[a]

Trait	CBL	WWT	WHT	FS	Weight1	BCS1	Weight2	BCS2	Weight3	BCS3	Weight5	BCS5
BWT	0.60*	0.49*	0.46*	0.47*	0.33*	-0.05	0.49*	0.10	0.47*	0.11	0.39*	0.05
CBL		0.35*	0.67*	0.74*	0.63*	-0.07	0.48*	-0.05	0.61*	0.02	0.52*	-0.12
WWT			0.68*	0.54*	0.27*	0.06	0.43*	0.24*	0.43*	0.17*	0.41*	0.17†
WHT				0.97*	0.55*	-0.15†	0.52*	-0.04	0.65*	-0.06	0.63*	-0.01
FS					0.58*	-0.16†	0.52*	-0.08	0.66*	0.01	0.61*	-0.09
Weight1						0.16†	0.53*	-0.04	0.68*	0.06	0.48*	-0.17†
BCS1							-0.12	0.22*	-0.10	0.19*	-0.19†	0.04
Weight2								0.49*	0.73*	0.27*	0.59*	0.16
BCS2									0.10	0.39*	0.04	0.31*
Weight3										0.41*	0.76*	0.03
BCS3											0.20*	0.43*
Weight5												0.37*

[a]BWT = birth weight, kg; CBL = cannon bone length, cm; WWT = weaning weight, kg; WHT = weaning height, cm; FS = frame score; Weight1 = cow weight at parity 1; BCS1 = cow body condition score at parity 1; Weight2 = cow weight at parity 2; BCS2 = cow body condition score at parity 2; Weight3 = cow weight at parity 3; BCS3 = cow body condition score at parity 3; Weight5 = cow weight at parity 5; BCS5 = cow body condition score at parity 5.

†Correlations are different from zero at $P < 0.10$

*Correlations are different from zero at $P < 0.05$

Analyses of variance for cow weight

As previously stated, there was near complete confounding involving sire breed and several frame score category designations, and therefore no results based on frame score designation alone are presented.

Among the three studies, females from study II were significantly heavier than females from studies I (36.2 kg) and III (63.9 kg) at the first parity (Table 4). Some of this difference in weight may be explained by age at first parity. The females in study II were bred to calve at approximately 2.5 years of age, whereas females in the other two studies were bred to calve at 2 years of age. There were no significant differences among cow weights in studies I, II, and III at second or third parities. At the fifth parity, females in study II, were heaviest ($P < 0.05$) when compared to females from studies I (58.1 kg) and III (66.6 kg) (Table 4).

Table 4. Least squares means and standard errors for cow weight at parity 1, 2, 3, and 5 in F_1 females across sire breed and study herd.

	Weight 1		Weight 2		Weight 3		Weight 5	
Herd[a]	LSM $\pm$ SE, kg	n	LSM $\pm$ SE, kg	n	LSM $\pm$ SE, kg	n	LSM $\pm$ SE, kg	n
1	467.6 $\pm$ 7.76[c]	155	491.8 $\pm$ 14.48	104	518.9 $\pm$ 12.22	61	525.3 $\pm$ 7.95[c]	44
2	503.8 $\pm$ 16.39[b]	112	490.3 $\pm$ 13.52	112	531.1 $\pm$ 19.78	111	583.4 $\pm$ 20.45[b]	106
3	439.9 $\pm$ 10.57[d]	140	498.4 $\pm$ 10.88	135	529.4 $\pm$ 14.73	131	516.8 $\pm$ 9.81[c]	114

[a]Herd 1 = Brahman bulls bred to Hereford and Angus dams in 1994 and 1995; Herd 2 = Angus, Brahman, Gir, Indu-Brazil, and Nellore bulls bred to Hereford dams in 1982-1985; Herd 3 = Boran, Brahman, and Tuli bulls bred to Angus and Hereford dams in 1992 and 1993.

[b, c, d] Least squares means in the same column without common superscript differ $P < 0.05$.

Cow weight at first, second, third, and fifth parities relative to frame size

Rankings of cow weight least squares means among studies remained the same for parity 1 with the model that included cow frame size. There were no differences among all herds for cow weight adjusted for cow frame size at parities 2 and 3 (Table 5). At parity 5, females from study II were heavier ($P < 0.05$) than females from studies I (60.5 kg) and III (65.9 kg). It should be noted, that the females from study I and study III did not appear to be heavier at parity 5 than at parity 3.

Table 5. Least squares means and standard errors for cow weight at parity 1, 2, 3, and 5 in F_1 females by study herd[a].

	Weight 1		Weight 2		Weight 3		Weight 5	
Herd[a]	LSM $\pm$ SE, kg	n	LSM $\pm$ SE, kg	n	LSM $\pm$ SE, kg	n	LSM $\pm$ SE, kg	n
1	464.6 $\pm$ 7.67[d]	155	483.7 $\pm$ 14.21	108	533.1 $\pm$ 11.99	48	518.9 $\pm$ 8.81[d]	46
2	509.5 $\pm$ 15.78[c]	112	485.1 $\pm$ 13.02	112	526.1 $\pm$ 18.25	111	579.4 $\pm$ 19.48[c]	106
3	420.2 $\pm$ 12.48[e]	140	483.4 $\pm$ 13.13	137	515.4 $\pm$ 15.51	132	513.5 $\pm$ 12.76[d]	111

[a]Frame size included in model

[b]Herd 1 = Brahman bulls bred to Hereford and Angus dams in 1994 and 1995; Herd 2 = Angus, Brahman, Gir, Indu-Brazil, and Nellore bulls bred to Hereford dams in 1982-1985; Herd 3 = Boran, Brahman, and Tuli bulls bred to Angus and Hereford dams in 1992 and 1993.

[c, d, e]Least squares means in the same column without common superscript differ $P < 0.05$.

Comparisons of weights due to frame size classification are discussed below, and organized by parity.

Parity 1. Small and medium frame females from study III were the lightest ($P < 0.05$) when compared to studies I and II. Small frame females from studies I and II were not different from each other; however, medium frame females from study II were the heaviest ($P < 0.05$) when compared to medium frame females from the other two studies. Large frame females from study III were numerically the lightest, although not different from females from study I (Table 6).

Parity 2. There were no differences among females within small, medium, or large frame size classification across the three studies (Table 7). Small frame females from study I where heavier than small frame females from study II or study III though the difference was not significant. Medium frame females from study II ranked heavier than medium frame females from study I or study III.

Large frame females from studies II and III were heavier (although not significant) than large frame females from study I. As frame size increased, cow weight appeared to increase, with the exception in study I where medium frame females appeared slightly lighter than small frame females.

Parity 3. There were no differences between studies II and III, and as frame size increased, cow weight increased in these same studies (Table 8). Small frame females from study I were heaviest ($P < 0.05$).

Parity 5. There were no differences among the three studies in small frame females. Medium and large frame females from study II were heaviest ($P < 0.05$). In study I, small and large frame females were heavier (68.9 and 28.4 kg, respectively) than medium frame females. In studies II and III, there was an increasing trend in cow weight as frame size increases, although there may be little difference between small and medium frame females in study III (Table 9).

Table 6. Least squares means and standard errors for weight of small, medium, and large frame first parity F_1 females.

	Small		Medium		Large	
Herd[a]	LSM ± SE	n	LSM ± SE	n	LSM ± SE	n
1	468.8 ± 8.79[b]	78	454.4 ± 11.14[b]	18	470.6 ± 8.13[b]	59
2	503.6 ± 19.43[b]	19	496.5 ± 16.25[c]	62	528.4 ± 17.48[c]	31
3	382.2 ± 24.43[c]	5	421.2 ± 10.88[d]	62	457.8 ± 10.79[b]	73

[a]Herd 1 = Brahman bulls bred to Hereford and Angus dams in 1994 and 1995; Herd 2 = Angus, Brahman, Gir, Indu-Brazil, and Nellore bulls bred to Hereford dams in 1982-1985; Herd 3 = Boran, Brahman, and Tuli bulls bred to Angus and Hereford dams in 1992 and 1993.

[b, c, d]Least squares means in the same column with uncommon superscript differ $P < 0.05$.

Table 7. Least squares means and standard errors for weight of small, medium, and large frame second parity F_1 females.

	Small		Medium		Large	
Herd[a]	LSM ± SE	n	LSM ± SE	n	LSM ± SE	n
1	479.2 ± 15.64	37	471.1 ± 17.32	15	500.8 ± 14.22	56
2	460.2 ± 17.86	19	484.6 ± 14.31	63	510.5 ± 14.33	30
3	460.1 ± 26.15	5	478.2 ± 11.66	62	511.9 ± 10.98	70

[a]Herd 1 = Brahman bulls bred to Hereford and Angus dams in 1994 and 1995; Herd 2 = Angus, Brahman, Gir, Indu-Brazil, and Nellore bulls bred to Hereford dams in 1982-1985; Herd 3 = Boran, Brahman, and Tuli bulls bred to Angus and Hereford dams in 1992 and 1993.

Table 8. Least squares means and standard errors for weight of small, medium, and large frame third parity F_1 females.

	Small		Medium		Large	
Herd[a]	LSM $\pm$ SE	n	LSM $\pm$ SE	n	LSM $\pm$ SE	n
1	569.6 $\pm$ 17.38[b]	6	500.7 $\pm$ 15.66	8	529.1 $\pm$ 13.03	34
2	496.0 $\pm$ 21.78[c]	19	522.2 $\pm$ 19.14	62	560.0 $\pm$ 19.24	30
3	496.3 $\pm$ 26.89[c]	4	506.8 $\pm$ 14.66	60	543.2 $\pm$ 13.94	68

[a]Herd 1 = Brahman bulls bred to Hereford and Angus dams in 1994 and 1995; Herd 2 = Angus, Brahman, Gir, Indu-Brazil, and Nellore bulls bred to Hereford dams in 1982-1985; Herd 3 = Boran, Brahman, and Tuli bulls bred to Angus and Hereford dams in 1992 and 1993.

[b, c]Least squares means in the same column with uncommon superscript differ $P < 0.05$.

Table 9. Least squares means and standard errors for weight of small, medium, and large frame fifth parity F_1 females.

	Small		Medium		Large	
Herd[a]	LSM $\pm$ SE	n	LSM $\pm$ SE	n	LSM $\pm$ SE	n
1	526.2 $\pm$ 14.35	14	498.2 $\pm$ 18.99[b]	7	532.5 $\pm$ 9.47[b]	25
2	553.8 $\pm$ 23.32	18	579.2 $\pm$ 20.20[c]	77	605.1 $\pm$ 20.50[c]	29
3	497.2 $\pm$ 33.57	5	498.6 $\pm$ 10.70[b]	50	544.7 $\pm$ 11.53[b]	59

[a]Herd 1 = Brahman bulls bred to Hereford and Angus dams in 1994 and 1995; Herd 2 = Angus, Brahman, Gir, Indu-Brazil, and Nellore bulls bred to Hereford dams in 1982-1985; Herd 3 = Boran, Brahman, and Tuli bulls bred to Angus and Hereford dams in 1992 and 1993.

[b, c, d]Least squares means in the same column with uncommon superscript differ $P < 0.05$.

Differences seen in cow weight at parity 1 could partly be explained by age, as the females in study II were bred to calve at approximately 2.5 years of age for parity 1 compared to the females in studies I and III which were bred to calve at 2 years of age for parity 1. Differences in cow weight could also be attributed to genetic influences such as different individual growth patterns across breeds and family lines, environmental/management effects in different years as well as potential interactions.

In the present study, cow age had an effect ($P < 0.001$) on cow weight at parities 1, 2, and 3 with models that excluded and included frame size. Similarly, Northcutt et al. (1992) reported that weight of Angus cows increased to 6 years of age. Hays and Brinks (1980) also found that cow weight, as well as cow height, increased through age 6 in Hereford cows. Further, they reported that the largest increase in weight was between 2 and 3 years of age. Alternatively, Brinks et al. (1962) found that Hereford cows gained weight until 8 years of age and later declined.

Carcass traits in steer mates of females

There is little information on how mature size of cows is related to carcass traits (Nephawe et al., 2004), and greater knowledge of the relationships among traits of economic importance is needed within the beef industry when considering improving carcass merit and female productivity.

Carcass traits (weight, fat thickness, marbling score and rib eye area) were evaluated in steer mates of the females evaluated for cow weights and body condition score. Additionally, frame score (based on weaning age and hip height) category (small, medium and large) was investigated as a fixed effect. The inclusion of the regression on carcass fat thickness within herd was also investigated alone and in combination with frame score category to study carcass weight and marbling score.

Carcass weight

Simple correlations among early growth measurements and carcass traits (marbling score (MARB), fat thickness (FT), rib eye area (REA), carcass weight (HCW), and USDA yield grade (YG)) for each of the three studies are found in Tables 10, 11, and 12.

Of the early growth measurements recorded, weaning weight (WWT) and weaning height (WHT) were the most highly correlated with carcass weight (HCW) in study I ($P < 0.05$) (Table 10). In study II, of all early growth measurements, WWT was most correlated with HCW followed by WHT (Table 11). Weaning height and steer frame score at weaning (FS) had the strongest correlations with HCW in study III, although the correlations between cannon bone length (CBL) and WWT were also high and significant (Table 12).

Table 10. Pearson correlations birth, weaning, and carcass traits of Brahman-sired F_1 steers born in 1994 and 1995[a]

Trait	CBL	WWT	WHT	FS	MARB	FT	REA	HCW	YG
BWT	0.62*	0.06	0.25*	0.48*	0.10	0.01	0.17*	0.29*	0.02
CBL		0.10	0.29*	0.44*	-0.05	-0.04	0.10	0.29*	0.03
WWT			0.83*	0.61*	0.27*	0.37*	0.29*	0.61*	0.46*
WHT				0.89*	0.36*	0.39*	0.05	0.61*	0.49*
FS					0.28*	0.32*	0.05	0.50*	0.36*
MARB						0.37*	0.06	0.34*	0.40*
FT							0.14†	0.50*	0.79*
REA								0.50*	0.14†
HCW									0.65*

[a]BWT = birth weight, kg; CBL = cannon bone length, cm; WWT = weaning weight, kg; WHT = weaning height, cm; FS = frame score at weaning; MARB = marbling score; FT = fat thickness, cm; REA = rib eye area, cm^2; HCW = hot carcass weight, kg; YG = USDA yield grade

†Correlations are different from zero at $P < 0.10$

*Correlations are different from zero at $P < 0.05$

Table 11. Pearson correlations birth, weaning, and carcass traits of Angus-, Brahman-, Gir-, Indu-Brazil-, and Nellore-sired F_1 steers born in 1982, 1983, 1984, and 1985[a]

Trait	CBL	WWT	WHT	FS	MARB	FT	REA	HCW	YG
BWT	0.74*	0.18*	0.48*	0.57*	-0.34*	-0.02	0.05	0.35*	0.18*
CBL		0.07	0.41*	0.62*	-0.32*	-0.13	0.04	0.15†	0.01
WWT			0.66*	0.49*	0.02	0.21*	0.47*	0.72*	0.21*
WHT				0.89*	-0.27*	-0.06	0.22*	0.53*	0.16†
FS					-0.32*	-0.01	0.14	0.39*	0.11
MARB						-0.08†	0.05	0.01	0.08
FT							-0.08	0.23*	0.68*
REA								0.61*	-0.41*
HCW									0.32*

[a]BWT = birth weight, kg; CBL = cannon bone length, cm; WWT = weaning weight, kg; WHT = weaning height, cm; FS = frame score at weaning; MARB = marbling score; FT = fat thickness, cm; REA = rib eye area, cm^2; HCW = hot carcass weight, kg; YG = USDA yield grade
†Correlations are different from zero at $P < 0.10$
*Correlations are different from zero at $P < 0.05$

Table 12. Pearson correlations birth, weaning, and carcass traits of Brahman-, Boran- and Tuli-sired F_1 steers born in 1992 and 1993[a]

Trait	CBL	WWT	WHT	FS	MARB	FT	REA	HCW	YG
BWT	0.64*	0.55*	0.57*	0.62*	-0.27*	-0.18*	0.18*	0.38*	-0.08
CBL		0.35*	0.65*	0.72*	-0.12	0.01	0.14†	0.52*	0.12
WWT			0.74*	0.66*	-0.18*	-0.17*	0.20*	0.50*	-0.05
WHT				0.96*	-0.16†	-0.11	0.19*	0.60*	0.02
FS					-0.16†	-0.09	0.15†	0.60*	0.06
MARB						0.07	-0.10	-0.09	0.11
FT							-0.17*	0.29*	0.88*
REA								0.41*	-0.45*
HCW									0.36*

[a]BWT = birth weight, kg; CBL = cannon bone length, cm; WWT = weaning weight, kg; WHT = weaning height, cm; FS = frame score; MARB = marbling score; FT = fat thickness, cm; REA = rib eye area, cm^2; HCW = hot carcass weight, kg; YG = USDA yield grade

†Correlations are different from zero at $P < 0.10$

*Correlations are different from zero at $P < 0.05$

Marbling score

Simple correlations among early growth measurements and marbling score (MARB) for each of the three studies are found in Tables 10, 11, and 12.

In study I, WWT, WHT, and FS were the only early growth measures correlated with MARB ($P < 0.05$), also these correlations were moderate and positive (Table 10). Of the early growth measures in study II, BWT, CBL, WHT, and FS were significantly ($P < 0.05$) correlated with marbling score. All significant correlations were moderate and negative (Table 11). All early growth measures in study III were negatively correlated with marbling score. BWT and WWT were correlated with MARB at a greater degree of significance ($P < 0.05$), than were WHT and FS ($P < 0.10$) (Table 12).

Sex specific traits

Very few studies have evaluated relationships of cow size and corresponding carcass weight in steer mate half sibs. In many situations possible antagonistic relationship(s) of traits in males and females exist (i.e. fat thickness is desirable in females for fertility but may not be desired, or discounted in feedlot steers). Birth measures and weaning traits were evaluated in their ability to predict cow weight and steer carcass weight.

Prediction of cow weight and steer carcass weight from birth and weaning traits

Regression analyses were conducted to assess the predictive ability of measures available on very young calves (birth weight and cannon bone length) for cow weight at parity 1 and steer carcass weight, as well as parity 5 and steer carcass weight. Results of these analyses are presented in Tables 13, 14, 15, and 16.

None of the R-square values for cow weight or steer carcass weight using birth traits (birth weight and cannon bone length) were very large. R-square values appeared higher for Brahman-sired females than Brahman-sired males in all three studies indicating that birth weight and cannon bone length would be better indicators of cow weight at parity 5 than steer carcass weight. The opposite trend (higher R-square values in steers than females) was seen in Gir-, Indu-Brazil, and Nellore-sired animals from study II and Tuli-sired animals in study III.

R-square values for cow weight at parity 5 and steer carcass weight using weaning measures (weaning weight and weaning height) are also found in Table 13. Several different trends were seen using weaning measures as compared to birth measures. Brahman-sired males from studies I and II had greater R-square values using weaning measures in prediction of carcass weight as compared to prediction of cow weight, the opposite of that seen using birth measures. Birth weight and cannon bone length were better indicators of steer carcass weight in Gir-sired steers from study II and Tuli-sired steers from study III; however, the trend was reversed when considering weaning measures. Weaning measures, like birth measures, were a better prediction of steer carcass weight than cow weight at parity 5 in Indu-Brazil- and Nellore-sired females from study II.

Table 13. R-square values for cow weight at parity 5 (F) and male carcass weight (M) by sire breed and study herd for regression models containing birth traits (birth weight and cannon bone length) and weaning traits (weaning weight and height)

Sire Breed	Herd[a]	Sex	Birth traits	Weaning traits
Brahman	1	F	0.40	0.38
		M	0.09	0.46
Angus	2	F	0.16	0.24
		M	0.06	0.41
Brahman	2	F	0.20	0.02
		M	0.01	0.67
Gir	2	F	0.36	0.46
		M	0.52	0.38
Indu-Brazil	2	F	0.16	0.32
		M	0.20	0.52
Nellore	2	F	0.00	0.02
		M	0.16	0.58
Brahman	3	F	0.32	0.25
		M	0.06	0.25
Boran	3	F	0.32	0.25
		M	0.13	0.25
Tuli	3	F	0.06	0.29
		M	0.24	0.13

[a]Herd 1 = Brahman bulls bred to Hereford and Angus dams in 1994 and 1995; Herd 2 = Angus, Brahman, Gir, Indu-Brazil, and Nellore bulls bred to Hereford dams in 1982-1985; Herd 3 = Boran, Brahman, and Tuli bulls bred to Angus and Hereford dams in 1992 and 1993.

Table 14. Regression coefficients for cow weight at parity 1 by sire breed and study herd for models containing birth traits (birthweight and cannon bone length) and weaning traits (weaning weight and height).

		Birth traits					Weaning traits				
			BWT, kg		CBL, cm			WWT, kg		WHT, cm	
Sire Breed	Herd	Intercept	Regression Coefficient	S.E.	Regression Coefficient	S.E.	Intercept	Regression Coefficient	S.E.	Regression Coefficient	S.E.
Brahman	1	14.19	3.87	1.75	8.43	6.90	-285.09	-0.97	0.39	8.02	2.47
Angus	2	249.89	9.92	3.23	-5.12	5.94	47.43	-0.38	1.37	4.45	11.12
Brahman	2	540.58	4.72	2.27	-8.46	6.89	174.35	0.09	0.44	2.48	3.23
Gir	2	769.29	16.99	3.99	-30.46	8.49	1278.41	2.28	0.89	-12.00	6.15
Indu-Brazil	2	234.30	4.86	2.40	1.07	7.51	55.88	-0.29	0.56	4.03	2.47
Nellore	2	467.84	0.77	1.94	-2.43	5.41	119.44	-0.14	0.36	3.00	2.62
Brahman	3	-288.58	-0.048	1.76	23.94	6.84	-363.56	-0.42	0.42	7.83	3.00
Boran	3	-232.28	-1.67	1.15	23.51	4.60	-299.90	-0.27	0.30	6.78	1.74
Tuli	3	-38.15	0.37	1.23	14.28	6.69	-2.15	-0.09	0.30	3.70	2.42

Table 15. Regression coefficients for cow weight at parity 5 by sire breed and study herd for models containing birth traits (birthweight and cannon bone length) and weaning traits (weaning weight and height).

		Birth traits					Weaning traits				
			BWT, kg		CBL, cm			WWT, kg		WHT, cm	
Sire Breed	Herd	Intercept	Regression Coefficient	S.E.	Regression Coefficient	S.E.	Intercept	Regression Coefficient	S.E.	Regression Coefficient	S.E.
Brahman	1	410.80	6.85	2.28	-5.11	9.00	-449.10	-0.94	0.40	10.28	2.67
Angus	2	369.23	3.45	2.73	0.22	5.05	-294.23	-0.39	0.85	8.43	6.65
Brahman	2	454.07	6.08	2.09	-4.28	6.32	338.42	0.07	0.42	1.31	3.11
Gir	2	685.04	10.84	4.38	-18.48	9.33	515.05	1.39	0.70	-2.68	4.83
Indu-Brazil	2	529.49	4.97	3.15	-5.62	9.89	166.40	0.43	0.64	2.59	2.78
Nellore	2	552.22	-0.22	2.27	-1.23	6.32	321.82	-0.05	0.43	1.79	3.12
Brahman	3	-113.31	2.98	1.78	18.10	6.93	-174.94	0.34	0.40	5.72	2.89
Boran	3	-73.51	1.96	1.92	16.67	7.78	-261.70	-0.04	0.44	6.89	2.66
Tuli	3	458.64	2.80	1.86	-2.17	8.31	-212.32	0.27	0.31	6.05	2.47

Table 16. Regression coefficients for steer carcass weight by sire breed and study herd for models containing birth traits (birthweight and cannon bone length) and weaning traits (weaning weight and height).

		Birth traits					Weaning traits				
			BWT, kg		CBL, cm			WWT, kg		WHT, cm	
Sire Breed	Herd	Intercept	Regression Coefficient	S.E.	Regression Coefficient	S.E.	Intercept	Regression Coefficient	S.E.	Regression Coefficient	S.E.
Brahman	1	152.58	0.89	0.71	3.68	2.65	111.82	0.46	0.13	0.86	0.93
Angus	2	256.08	1.12	1.35	-0.43	3.45	-93.03	0.59	0.36	2.44	1.81
Brahman	2	302.70	0.77	1.31	-1.06	2.25	144.93	0.77	0.15	-0.10	1.03
Gir	2	250.98	5.85	1.16	-6.09	3.81	300.74	1.06	0.35	-2.09	1.83
Indu-Brazil	2	420.78	2.22	1.59	-7.33	4.02	161.95	0.94	0.28	-0.63	1.31
Nellore	2	207.44	2.39	1.81	-0.23	5.66	97.29	0.83	0.24	0.23	1.17
Brahman	3	135.73	0.65	0.81	4.46	4.38	-100.70	0.00	0.20	3.49	1.63
Boran	3	42.43	0.42	0.59	7.13	3.39	-3.02	0.32	0.15	1.86	1.29
Tuli	3	-11.40	0.35	0.97	11.40	3.90	-114.74	0.02	0.21	3.50	1.86

Correspondence between sire solutions

Very few studies have tried to quantify relationships between sex-specific traits in female and male relatives. Nephawe et al. (2004) utilized mixed animal model analyses where the sex-specific traits were fitted as correlated traits. In an attempt to study this component in these data, correlations among the sire solutions in the cow and steer analyses were calculated, which is a much less sophisticated than that utilized by Nephawe et al. (2004).

Tables 17 through 25 provide simple correlations of sire breed solutions for cow weight at parity 1, parity 5, and steer carcass weight individually for each sire breed and study combination. Few correlations between cow weight at parity 5 and steer carcass weight were significant, some of which was due to the small number of observations per sire. Patterns among these correlations were quite variable across these sire breeds. Sire solutions for cow weights at parities 1 and 5 were strong in most females with the exception of Nellore- (Table 22) and Tuli-sired females (Table 25). Cow weight at parity 5 and steer carcass weight of F_1 Gir were strongly, positively correlated ($P < 0.10$, Table 20); whereas, the two traits in F_1 Indu-Brazil were strongly, negatively correlated ($P < 0.05$, Table 21). In several cases, correlations between sire solutions for female weight and carcass weight were zero or even substantially negative (but not all of these were significant).

Table 17. Pearson correlations sire solutions for cow weight at parity 1, cow weight at parity 5, and steer carcass weight for Brahman-sired females and sibling steers born in 1994 and 1995

Trait	Cow weight parity 5	Carcass weight
Cow weight parity 1	0.62[a]	-0.08
	0.04[b]	0.80
	11[c]	12
Cow weight parity 5		0.01
		0.98
		10

[a] Pearson correlation
[b] *P*-value
[c] number of observations

Table 18. Pearson correlations sire solutions for cow weight at parity 1, cow weight at parity 5, and steer carcass weight for Angus-sired females and sibling steers born in 1982, 1983, 1984, and 1985

Trait	Cow weight parity 5	Carcass weight
Cow weight parity 1	0.62[a]	-0.30
	0.19[b]	0.52
	6[c]	7
Cow weight parity 5		0.20
		0.71
		6

[a] Pearson correlation
[b] *P*-value
[c] number of observations

Table 19. Pearson correlations sire solutions for cow weight at parity 1, cow weight at parity 5, and steer carcass weight for Brahman-sired females and sibling steers born in 1982, 1983, 1984, and 1985

Trait	Cow weight parity 5	Carcass weight
Cow weight parity 1	0.51[a]	-0.16
	0.03[b]	0.59
	18[c]	14
Cow weight parity 5		-0.09
		0.74
		15

[a] Pearson correlation
[b] *P*-value
[c] number of observations

Table 20. Pearson correlations sire solutions for cow weight at parity 1, cow weight at parity 5, and steer carcass weight for Gir-sired females and sibling steers born in 1982, 1983, 1984 and 1985

Trait	Cow weight parity 5	Carcass weight
Cow weight parity 1	0.85[a]	-0.57
	0.07[b]	0.31
	5[c]	5
Cow weight parity 5		0.82
		0.09
		5

[a] Pearson correlation
[b] *P*-value
[c] number of observations

Table 21. Pearson correlations sire solutions for cow weight at parity 1, cow weight at parity 5, and steer carcass weight for Indu-Brazil-sired females and sibling steers born in 1982, 1983, 1984 and 1985

Trait	Cow weight parity 5	Carcass weight
Cow weight parity 1	0.51[a]	-0.14
	0.19[b]	0.77
	8[c]	7
Cow weight parity 5		-0.89
		0.02
		6

[a] Pearson correlation
[b] *P*-value
[c] number of observations

Table 22. Pearson correlations sire solutions for cow weight at parity 1, cow weight at parity 5, and steer carcass weight for Nellore-sired females and sibling steers born in 1982, 1983, 1984, and 1985

Trait	Cow weight parity 5	Carcass weight
Cow weight parity 1	0.18[a]	-0.34
	0.60[b]	0.37
	11[c]	9
Cow weight parity 5		0.04
		0.93
		9

[a] Pearson correlation
[b] *P*-value
[c] number of observations

Table 23. Pearson correlations sire solutions for cow weight at parity 1, cow weight at parity 5, and steer carcass weight for Brahman-sired females and sibling steers born in 1992 and 1993

Trait	Cow weight parity 5	Carcass weight
Cow weight parity 1	0.50[a]	0.39
	0.08[b]	0.18
	13[c]	13
Cow weight parity 5		0.08
		0.80
		13

[a] Pearson correlation
[b] *P*-value
[c] number of observations

Table 24. Pearson correlations sire solutions for cow weight at parity 1, cow weight at parity 5, and steer carcass weight for Boran-sired females and sibling steers born in 1992 and 1993

Trait	Cow weight parity 5	Carcass weight
Cow weight parity 1	0.79[a]	0.38
	0.03[b]	0.53
	8[c]	5
Cow weight parity 5		0.13
		0.83
		5

[a] Pearson correlation
[b] *P*-value
[c] number of observations

Table 25. Pearson correlations sire solutions for cow weight at parity 1, cow weight at parity 5, and steer carcass weight for Tuli-sired females and sibling steers born in 1992 and 1993

Trait	Cow weight parity 5	Carcass weight
Cow weight parity 1	0.37[a]	0.49
	0.37[b]	0.32
	8[c]	6
Cow weight parity 5		0.27
		0.66
		5

[a] Pearson correlation
[b] *P*-value
[c] number of observations

In recent years, beef producers have shifted their focus with more attention to endpoint characters while continuing a goal of maximizing profit. Weight traits, carcass weight or mature cow weight, for instance, have intermediate optimums (Nephawe et al., 2004). There is a high, positive genetic correlation between the two traits, carcass weight and mature cow weight (0.81 as reported by Nephawe et al., 2004). Therefore, selecting for a reduction in cow weight could lead to carcass weights becoming too light, or the reverse could also be seen where selecting for increased carcass size may lead to much larger mature size cows.

Nephawe et al. (2004) found genetic correlations between mature cow weight and carcass traits such as retail product, fat, and adjusted fat to be low and not different from zero. Speer (1993) and Nephawe et al. (2004) reported genetic correlations between mature size and marbling that were low. Nephawe et al. (2004) also found genetic correlation between longissimus muscle area and mature size to be moderate

(0.34), suggesting that selecting bulls to have smaller daughters at maturity could also produce steers with smaller longissimus muscle area, but the impact would not be as great as with weights.

Distribution of frame size categories

Originally, it was intended to have formal comparisons of frame size categories (small, medium, and large) based on feeder calf size status relative to weaning-age measures. However, the degree of confounding of these category levels with sire breeds in these data prevented meaningful interpretation of frame size category alone. The distributions of these frame size categories are shown in Tables 26 through 34.

Table 26. Frequency of number of females by frame size through the eighth parity in Brahman-sired F_1 females born in 1994 and 1995

	Parity								
	1	2	3	4	5	6	7	8	Total
Large	83	61	40	26	25	25	19	15	294
Medium	28	14	10	6	6	5	5	2	76
Small	5	2	0	0	0	0	0	0	7
Total	116	77	50	32	31	30	24	17	377

Table 27. Frequency of number of females by frame size through the eighth parity in Angus-sired F_1 females born in 1982, 1983, 1984, and 1985

	Parity								
	1	2	3	4	5	6	7	8	Total
Large	0	0	0	0	0	0	0	0	0
Medium	1	1	1	1	1	1	1	1	8
Small	17	15	14	14	15	12	12	10	109
Total	18	16	15	15	16	13	13	11	117

Table 28. Frequency of number of females by frame size through the eighth parity in Brahman-sired F_1 females born in 1982, 1983, 1984, and 1985

	Parity								
	1	2	3	4	5	6	7	8	Total
Large	9	9	10	9	8	9	7	6	67
Medium	31	27	26	27	26	25	26	27	215
Small	6	6	6	4	4	4	3	3	36
Total	46	42	42	40	38	38	36	36	318

Table 29. Frequency of number of females by frame size through the eighth parity in Gir-sired F_1 females born in 1982, 1983, 1984, and 1985

	Parity								
	1	2	3	4	5	6	7	8	Total
Large	0	0	0	0	0	0	0	0	0
Medium	9	10	9	9	8	8	9	9	71
Small	6	6	7	6	7	6	6	6	50
Total	15	16	16	15	15	14	15	15	121

Table 30. Frequency of number of females by frame size through the eighth parity in Indu-Brazil-sired F_1 females born in 1982, 1983, 1984, and 1985

	Parity								
	1	2	3	4	5	6	7	8	Total
Large	10	10	9	9	9	7	8	5	67
Medium	6	6	7	5	5	5	5	6	45
Small	4	4	5	4	4	4	3	4	32
Total	20	20	21	18	18	16	16	15	144

Table 31. Frequency of number of females by frame size through the eighth parity in Nellore-sired F_1 females born in 1982, 1983, 1984, and 1985

	Parity								
	1	2	3	4	5	6	7	8	Total
Large	5	3	3	3	3	3	3	3	26
Medium	20	20	20	21	21	20	18	18	158
Small	1	1	1	1	1	1	1	1	8
Total	26	24	24	25	25	24	22	22	192

Table 32. Frequency of number of females by frame size through the eighth parity in Brahman-sired F_1 females born in 1992 and 1993

	Parity								
	1	2	3	4	5	6	7	8	Total
Large	70	55	45	45	37	34	34	31	351
Medium	11	8	7	7	5	4	4	4	50
Small	11	8	7	7	5	4	4	4	50
Total	81	63	52	52	41	38	38	35	401

Table 33. Frequency of number of females by frame size through the eighth parity in Boran-sired F_1 females born in 1992 and 1993

	Parity								
	1	2	3	4	5	6	7	8	Total
Large	22	15	13	14	11	10	9	9	103
Medium	21	24	20	16	16	16	17	16	146
Small	2	1	1	1	1	1	1	1	9
Total	45	40	34	31	28	27	27	26	258

Table 34. Frequency of number of females by frame size through the eighth parity in Tuli-sired F_1 females born in 1992 and 1993

	Parity								
	1	2	3	4	5	6	7	8	Total
Large	12	15	12	12	11	11	11	10	94
Medium	50	43	36	36	33	32	26	22	278
Small	4	4	4	2	1	1	1	1	18
Total	66	62	52	50	45	44	38	33	390

SUMMARY AND CONCLUSIONS

The goal of this project was to evaluate relationships among multiple size traits taken at different times in the lives of F_1 cattle that were sired by several tropically adapted breeds in central Texas. The objectives of this study were to: (1) evaluate cow productivity in regard to frame size designation determined as heifers at weaning, (2) evaluate early measures of calf size (at birth and weaning) for prediction of mature size in cows and carcass weight and other carcass traits in steer mates, and (3) evaluate relationships among size and productivity traits in cows and the relationships of these cow traits with carcass traits among their steer mates.

Regression and correlation analyses were conducted to assess the predictive ability of measures available on very young calves (birth weight and cannon bone length) as well as calves at weaning (weaning weight and hip height) for cow weight at parity 5 and steer carcass weight. Regarding birth measures, the largest R-square values were in Brahman-sired females than in Brahman-sired males in all three studies. The opposite was seen in Gir-, Indu-Brazil-, and Nellore-sired animals from study II and Tuli-sired animals from study III. Early measurements would be a better indicator of cow weight at parity 5 than steer carcass weight when considering Brahman-sired animals; however, the opposite was indicated in Gir-, Indu-Brazil-, Nellore-, and Tuli-sired animals. Regarding use of weaning measures to assess cow weight at parity 5 and steer carcass weight, trends were very different from those seen in the analysis using birth measurements (calf birth weight and cannon bone length). Opposite that seen when using early life measurements, where birth weight and cannon bone length would better indicate cow weight at parity 5 than steer carcass weight, weaning measurements (weight and height) would better indicate steer carcass weight than cow weight at parity 5 for Brahman-sired animals in all three study herds. Additionally, weaning measurements were also a better measure of steer carcass weight than cow weight at parity 5 in Angus-, Indu-Brazil-, and Nellore-sired animals. For Indu-Brazil- and Nellore-sired animals, this is the same trend that was seen when using early life measurements as a predictor of size later in life. In contrast, the opposite trend was seen in Gir- and Tuli-sired animals. When considering weight and height measured at weaning, these measures were a better indicator of cow weight at parity 5 than steer carcass weight. Neither early life measures nor weaning measures appear to be at a distinct advantage to the other when predicting cow weight at parity 5 or steer carcass weight. Only in Indu-Brazil- and Nellore-sired animals was the same trend seen when early life measures or weaning measures were used for analysis, therefore, additional analyses should be investigated when considering prediction of mature size.

Simple correlations of sire breed solutions for cow weight at parity 1, parity 5, and steer carcass weight were calculated for each sire breed and study combination, and few were significant, while most were quite variable across sire breeds. When considering the sire breeds present in the three study herds, the only significant ($P < 0.10$) correlations between cow weight at parity 5 and steer carcass weight were seen in Gir-sired animals (0.82) and in Indu-Brazil-sired animals (-0.89). Although statistically non-significant, all other sire breeds across the three study herds had correlation values for cow weight at parity 5 and steer carcass weight that were low or negative, and the same was seen for cow weight at parity 1 and steer carcass weight.

Although weaning age and size are used to classify many U.S. cattle in regard to feeder calf grades, these results suggest that the use of weaning measurements to determine an animal's mature size may not be an accurate classification of mature size across different genetic types. Here, cow frame score was calculated using that female's weaning hip height and corresponding age in days with the Beef Improvement Federation equation (Dolezal et al., 2002) for frame score, and frame size categories of small, medium, and large were then assigned according to Hammack and Gill (2009) with small being less than 4.0, medium being over 4.0, but less than 5.5, and large being over 5.5. This classification scheme automatically produced high levels of confounding across breed types in these studies, preventing a useful comparison of frame size category as a stand-alone evaluation, and reiterated the thoughts of Buttram and Willham (1989) who stated that cattle size and breed were practically inseparable. In the literature where cow size has been classified into Small, Medium and Large groupings, these have not been consistent (Table 35). The amount of literature available on mature cow size and its relationship to steer carcass traits is limited, especially when considering *Bos indicus* and *Bos indicus* influenced animals, but this area deserves much more attention to assist producers in the future, especially those utilizing tropically adapted genetics, in making breeding decisions concerning mature cattle size.

Table 35. Summary of some studies that have classified mature cow size into categories

Author(s)	Year	Breed(s) in study	Cow size	Cow size (height)	Cow size (weight)
Vargas et al.	1999	Brahman	Small	115 to 126 cm	
			Medium	127 to 133 cm	
			Large	134 to 145 cm	
				(Hip height at 18 mo)	
Taylor et al.	2008	Santa Gertrudis	Small	< 124 cm	
			Medium	124 to 135 cm	
			Large	> 135 cm	
				(Hip height at 18 mo)	
Buttram and Willham	1989	Jersey, Angus, Simmental	Small	110 cm	258 kg
			Medium	115 cm	422 kg
			Large	120 cm	318 kg
				(Actual yearling height)	(Actual yearling weight)
Olson, T.A.	1993	Brahman	Small	117 cm	
			Medium	122 cm	
			Large	125 cm	
				(Hip height at maturity)	
Olson et al.	1982	Hereford	Small	115.6 cm	450.9 kg
			Medium	121.1 cm	517.1 kg
			Large	122.8 cm	566.8 kg
			Very Large	129.6 cm	646.9 kg

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